

The Width of a CME and the Source of the Driving Magnetic Explosion

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We show that the strength of the magnetic field in the area covered by the flare arcade following a CME-producing ejective solar eruption can be estimated from the final angular width of the CME in the outer corona and the final angular width of the flare arcade. We assume (1) the flux-rope plasmoid ejected from the flare site becomes the interior of the CME plasmoid, (2) in the outer corona the CME is roughly a "spherical plasmoid with legs" shaped like a light bulb, and (3) beyond some height in or below the outer corona the CME plasmoid is in lateral pressure balance with the surrounding magnetic field. The strength of the nearly radial magnetic field in the outer corona is estimated from the radial component of the interplanetary magnetic field measured by Ulysses. We apply this model to three well-observed CMEs that exploded from flare regions of extremely different size and magnetic setting. In each event, the estimated source-region field strength is appropriate for the magnetic setting of the flare. This agreement indicates via the model that CMEs (1) are propelled by the magnetic field of the CME plasmoid pushing against the surrounding magnetic field, and (2) can explode from flare regions that are laterally far offset from the radial path of the CME in the outer corona.

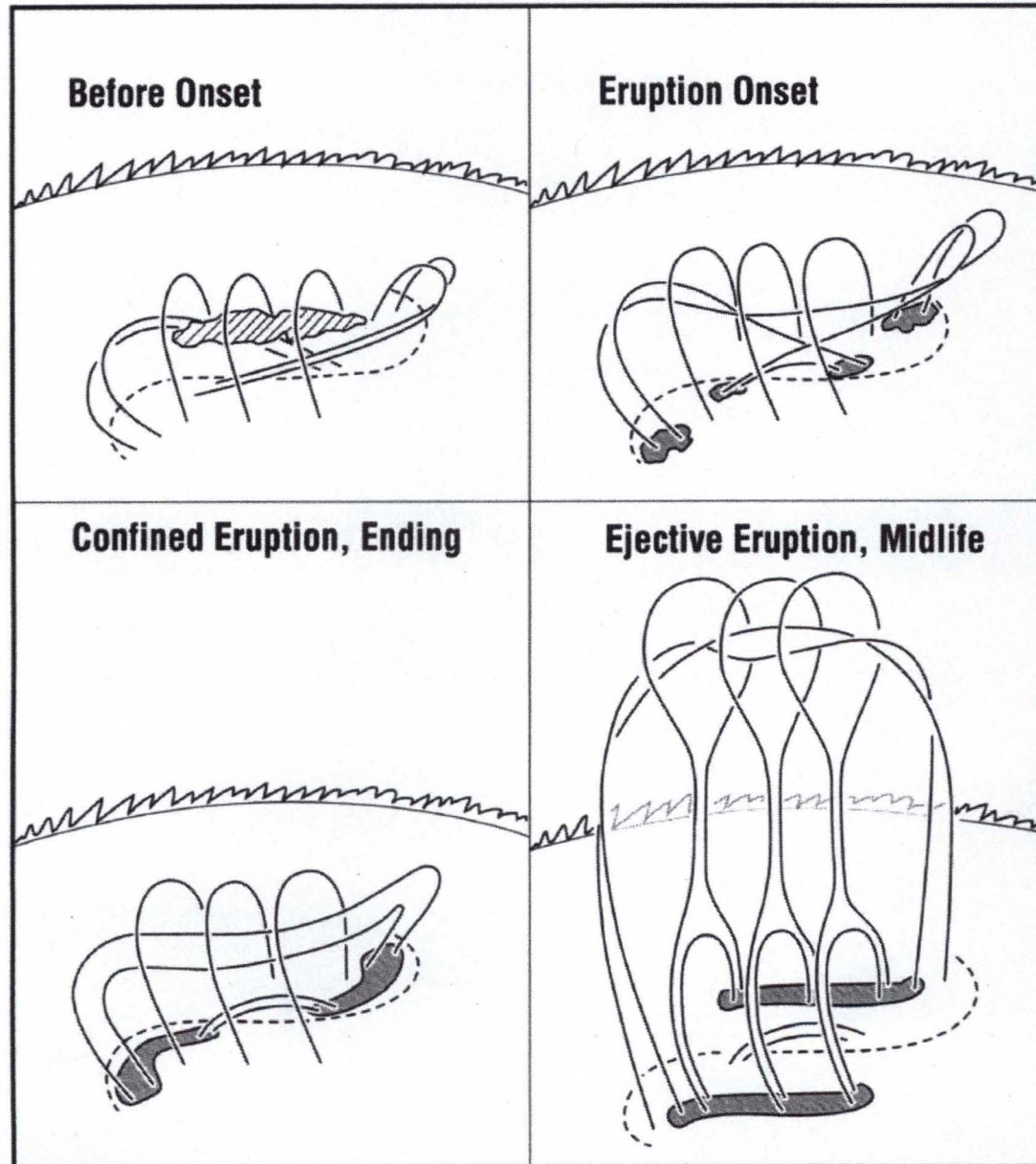
Main Points

- The “standard model” for CME production is basically the true physical picture for all major CMEs.
- A CME is a magnetically inflated (low-beta) “plasmoid with legs.”
 - Built and unleashed by tether-cutting reconnection.
 - Propelled by its own magnetic field pushing on the surrounding field.
- The tether-cutting reconnection also produces a flare arcade at the source of the driving magnetic explosion.
- The source region can be anywhere in the lateral span of the CME, from about centered to far off to one side.

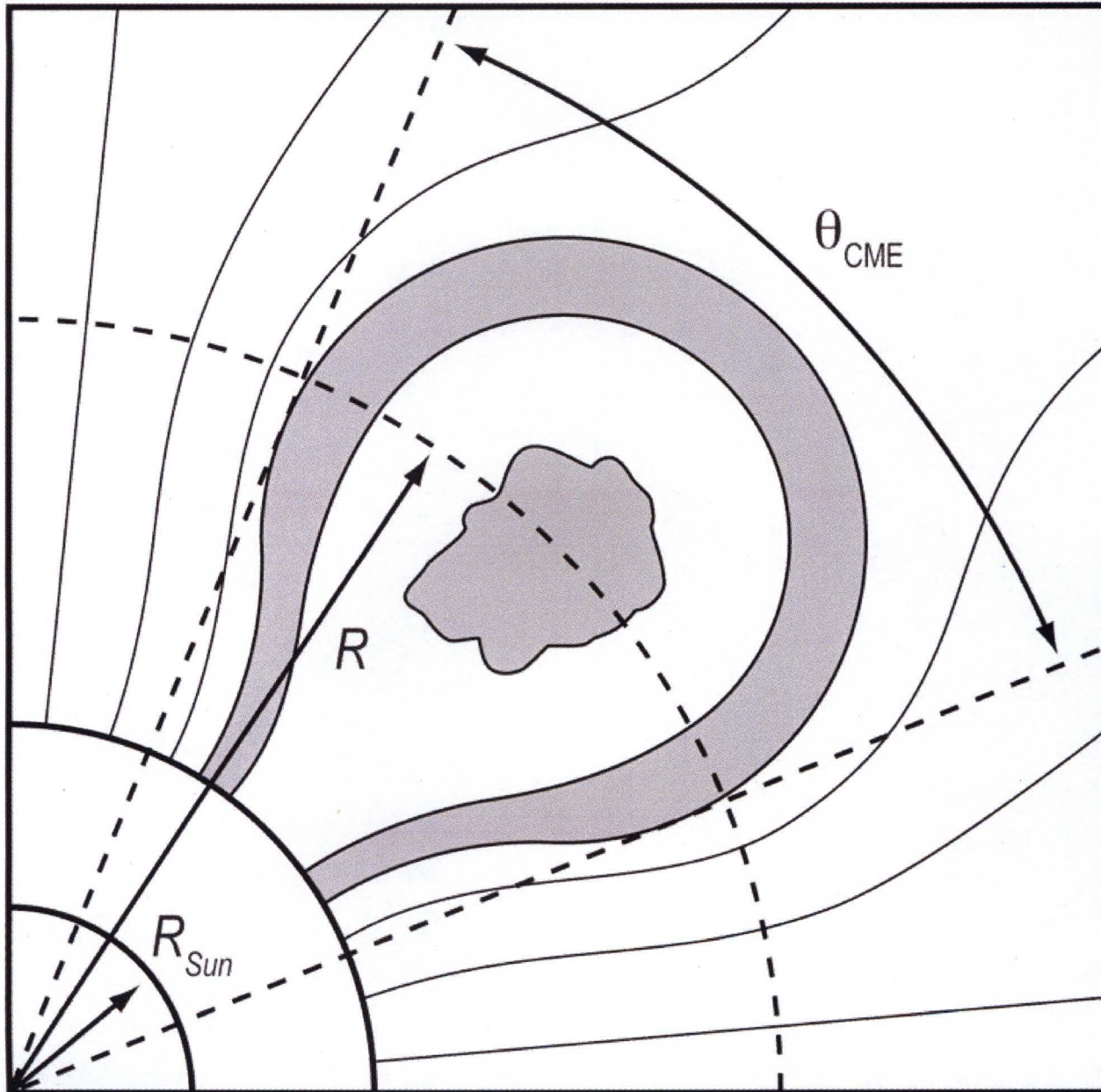
Outline

- **Standard Scenario for CME Production**
- **New Observational Test**

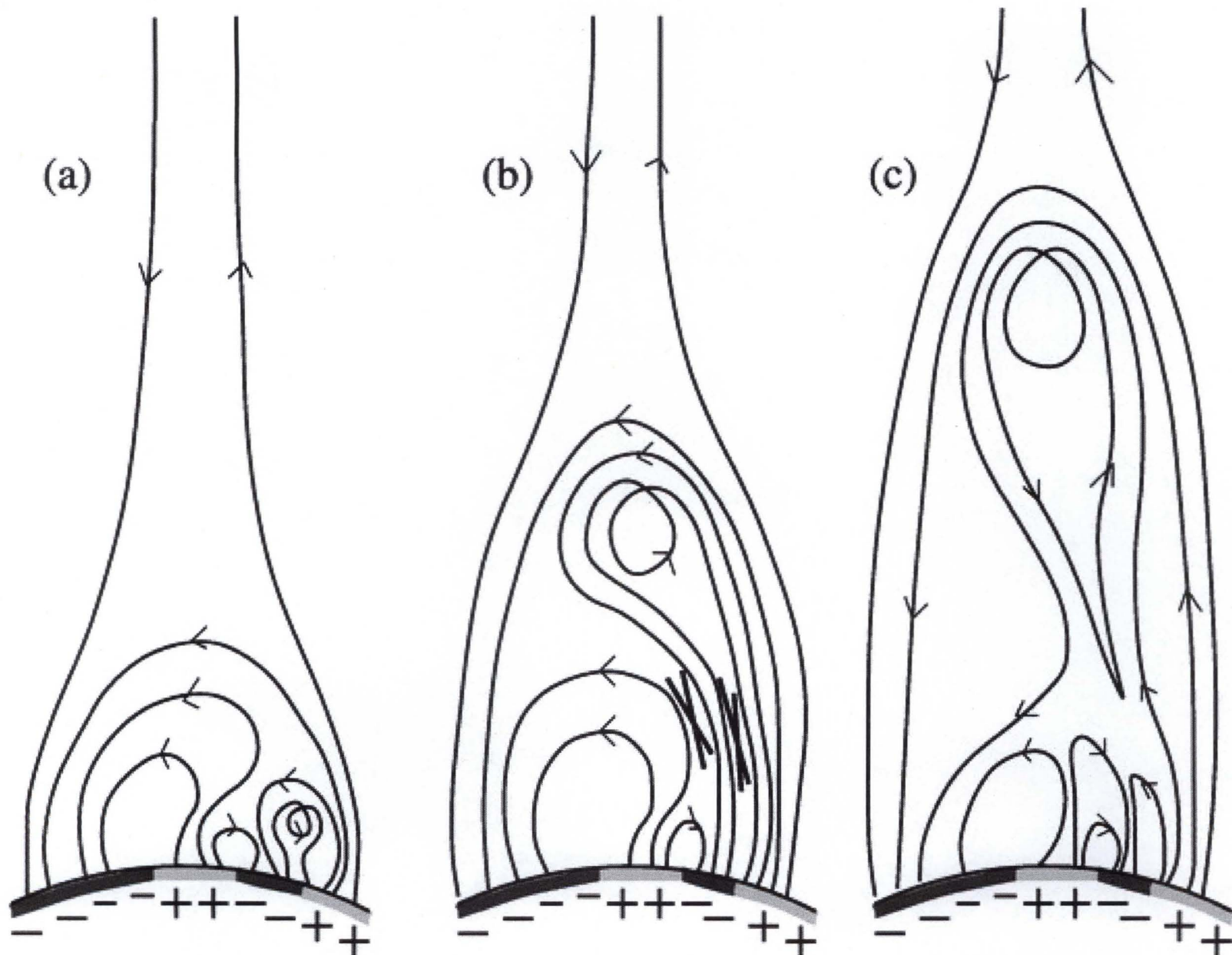
Birth and Release of the CME Plasmoid



Resulting CME in Outer Corona



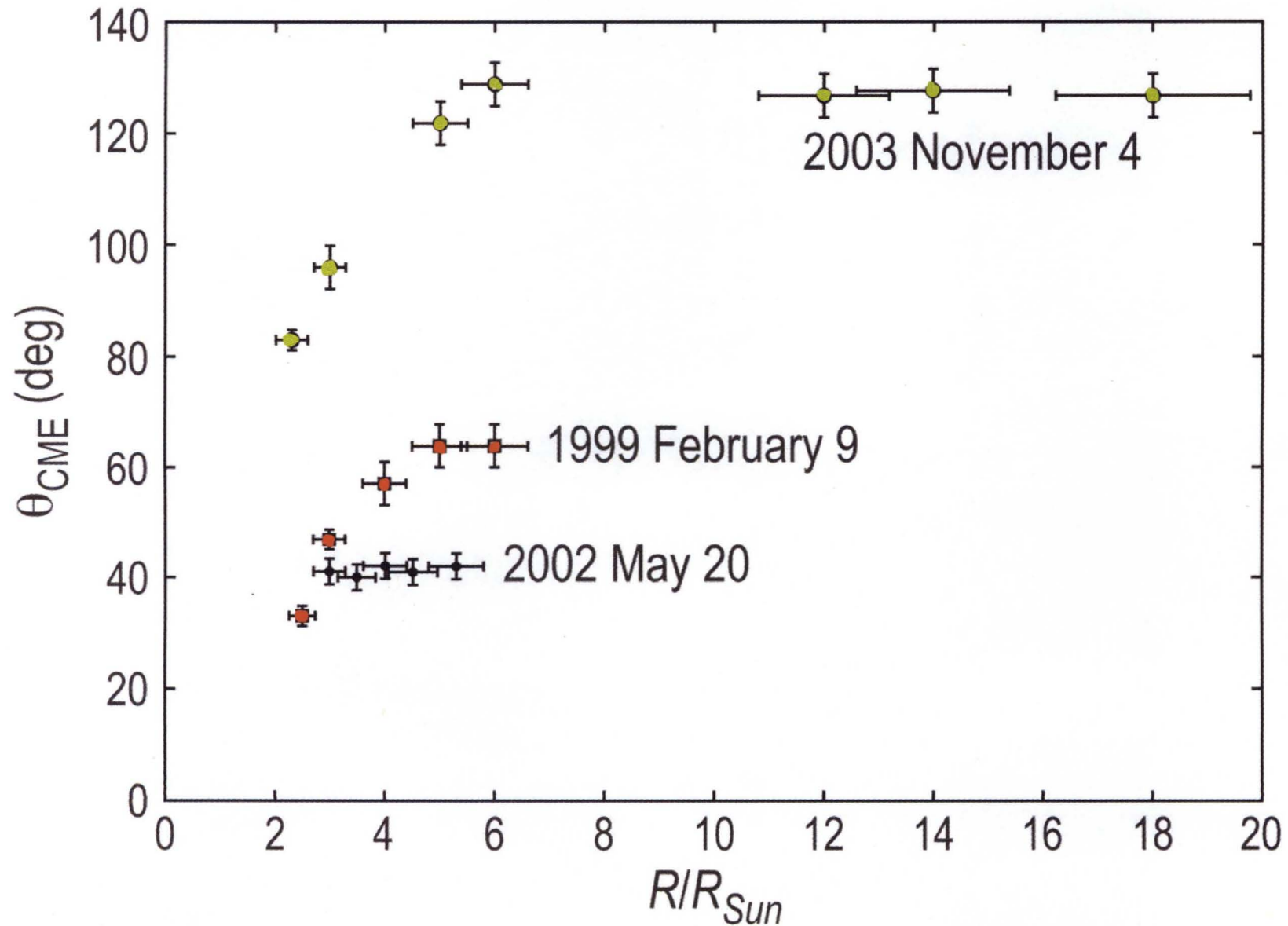
Governing Role of Surrounding Field



Testable Prediction of the Standard Scenario Magnetic Bubble CME Model:

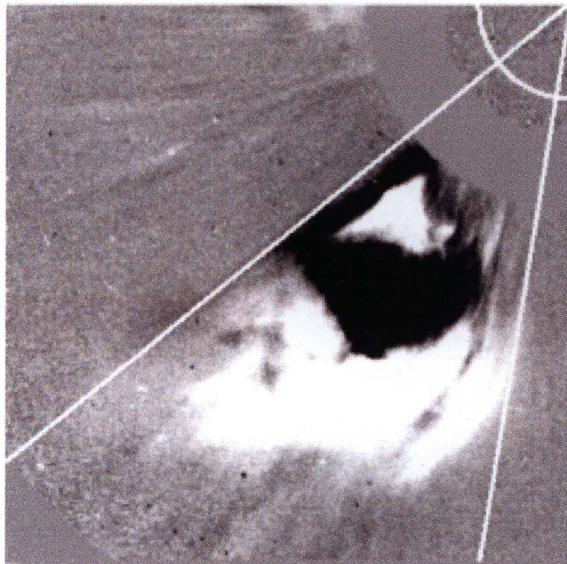
$$B_{\text{Flare}} \approx 1.4(\theta_{\text{CME}}/\theta_{\text{Flare}})^2 \text{ Gauss}$$

Measured Angular Widths of 3 CMEs



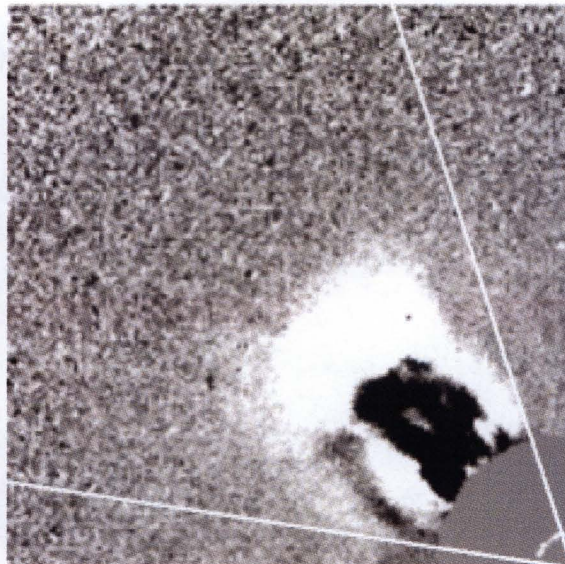
LASCO Image of each CME at Final Width

2002 May 20



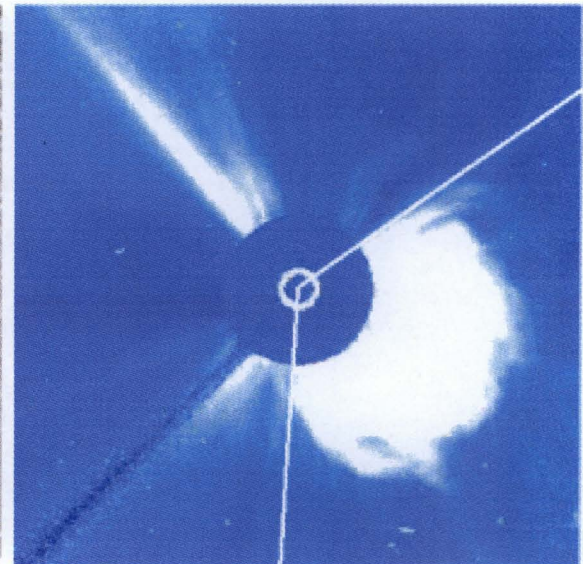
C2 Difference Image

1999 Feb 9



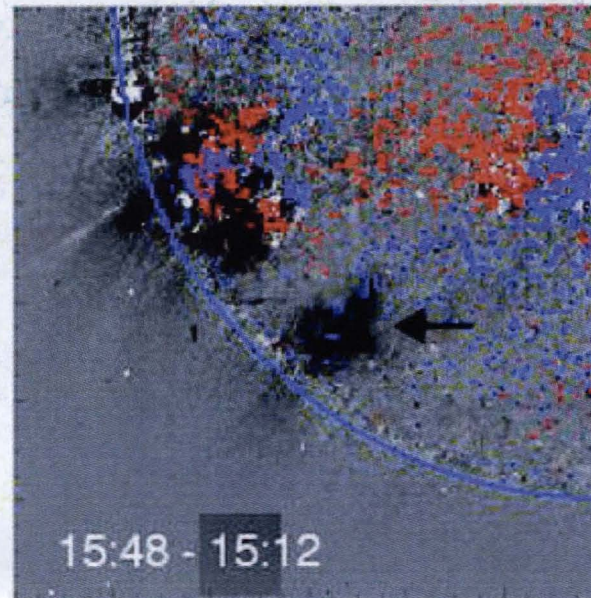
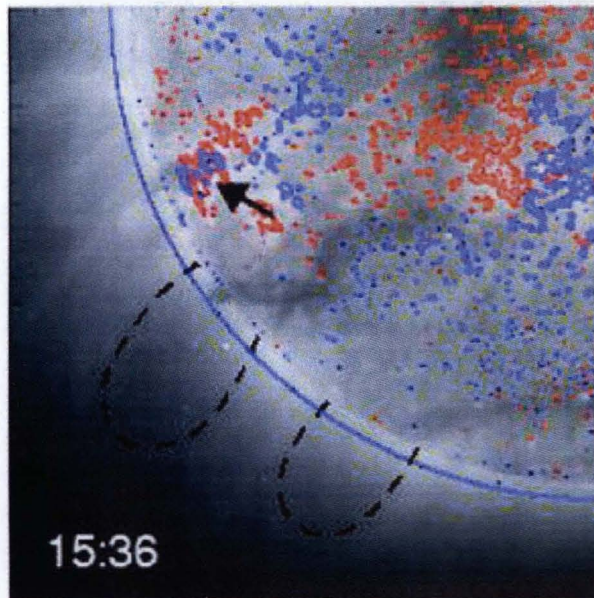
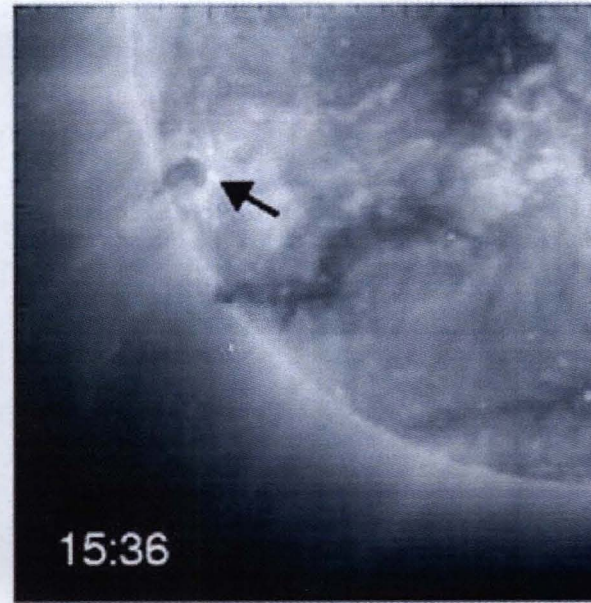
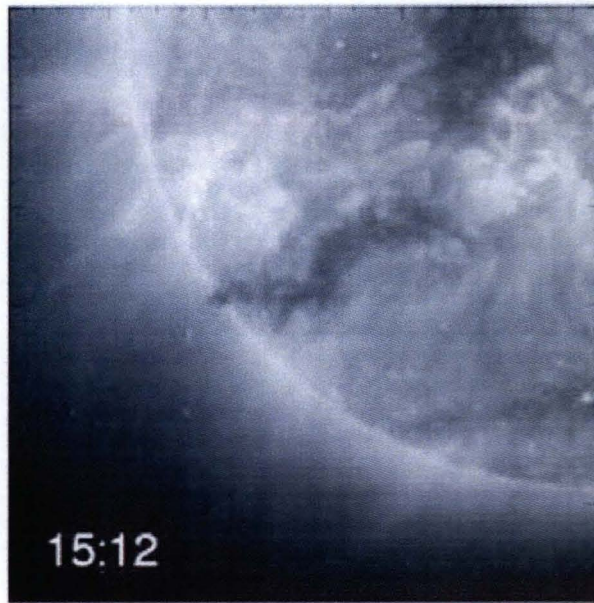
C3 Difference Image

2003 Nov 4

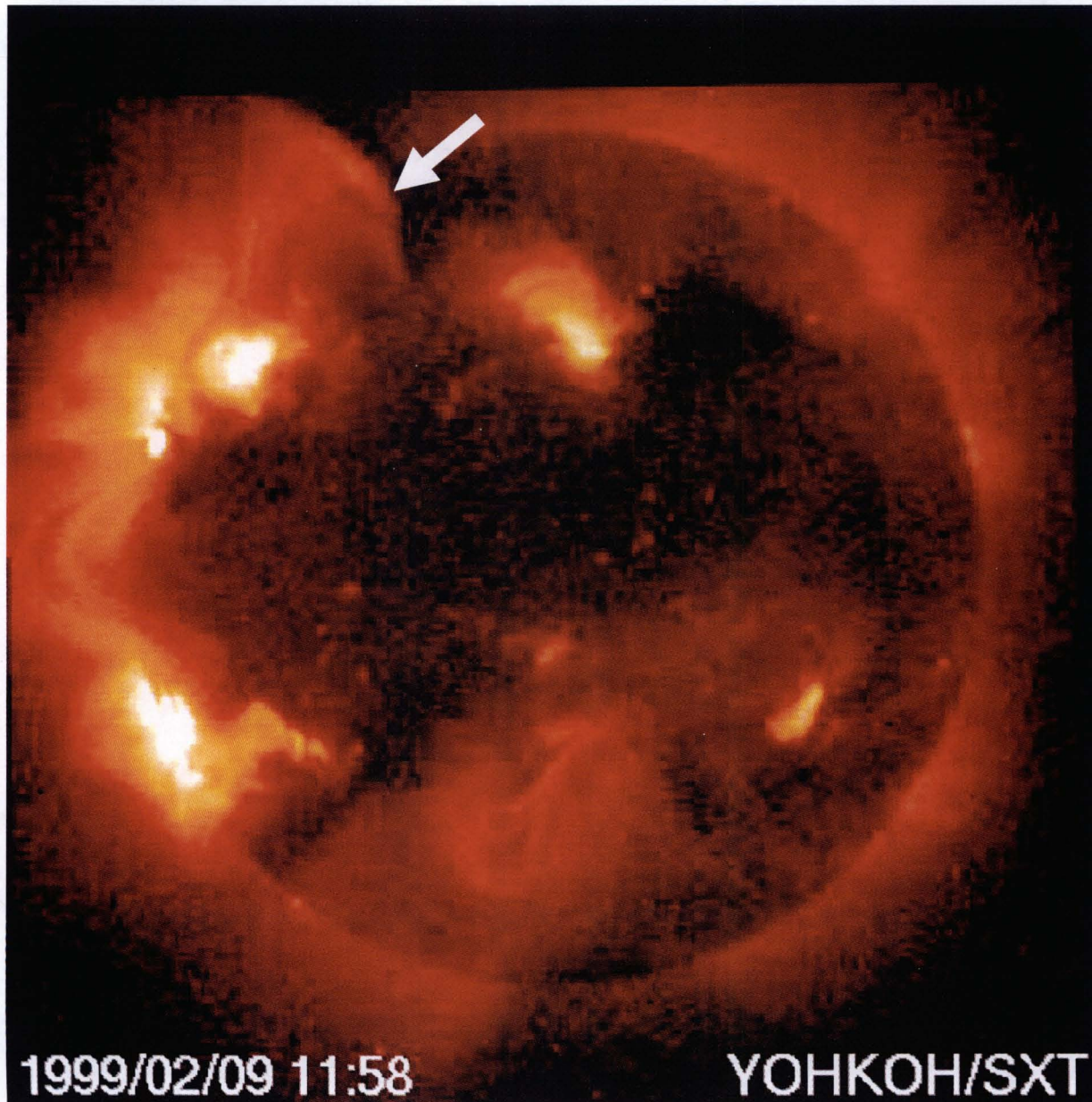


C3 Normal Image

Source of the CME of 2002 May 20

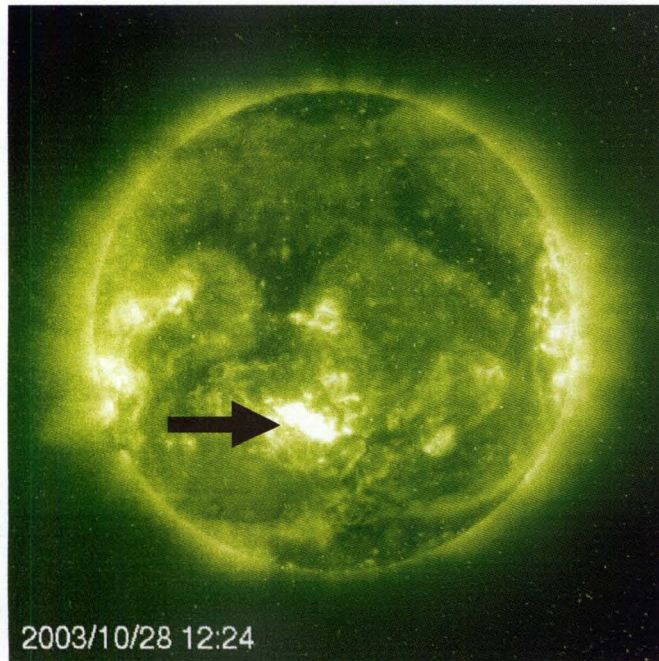


Source of the CME of 1999 Feb 9



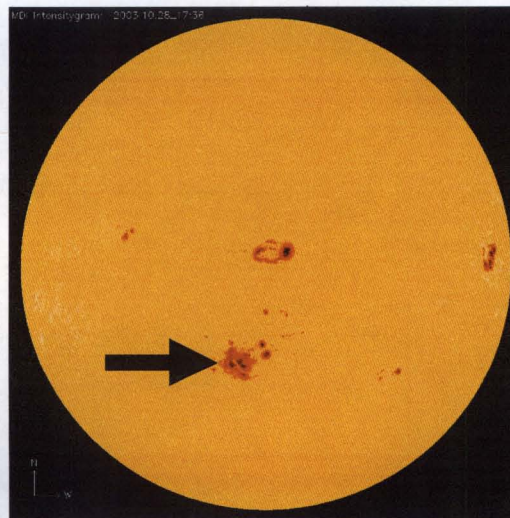
Source of the CME of 2003 Nov 4

Oct 28 X17 Flare Arcade



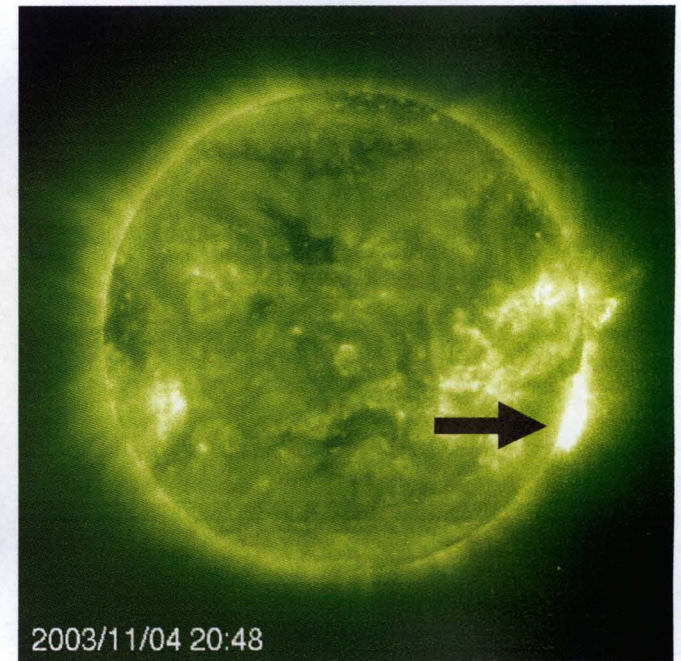
EIT 195 Å Corona

**Giant δ Sunspot Centered
Under Flare Arcade**



MDI Photosphere

Nov 4 X20 Flare Arcade



EIT 195 Å Corona

Test Results

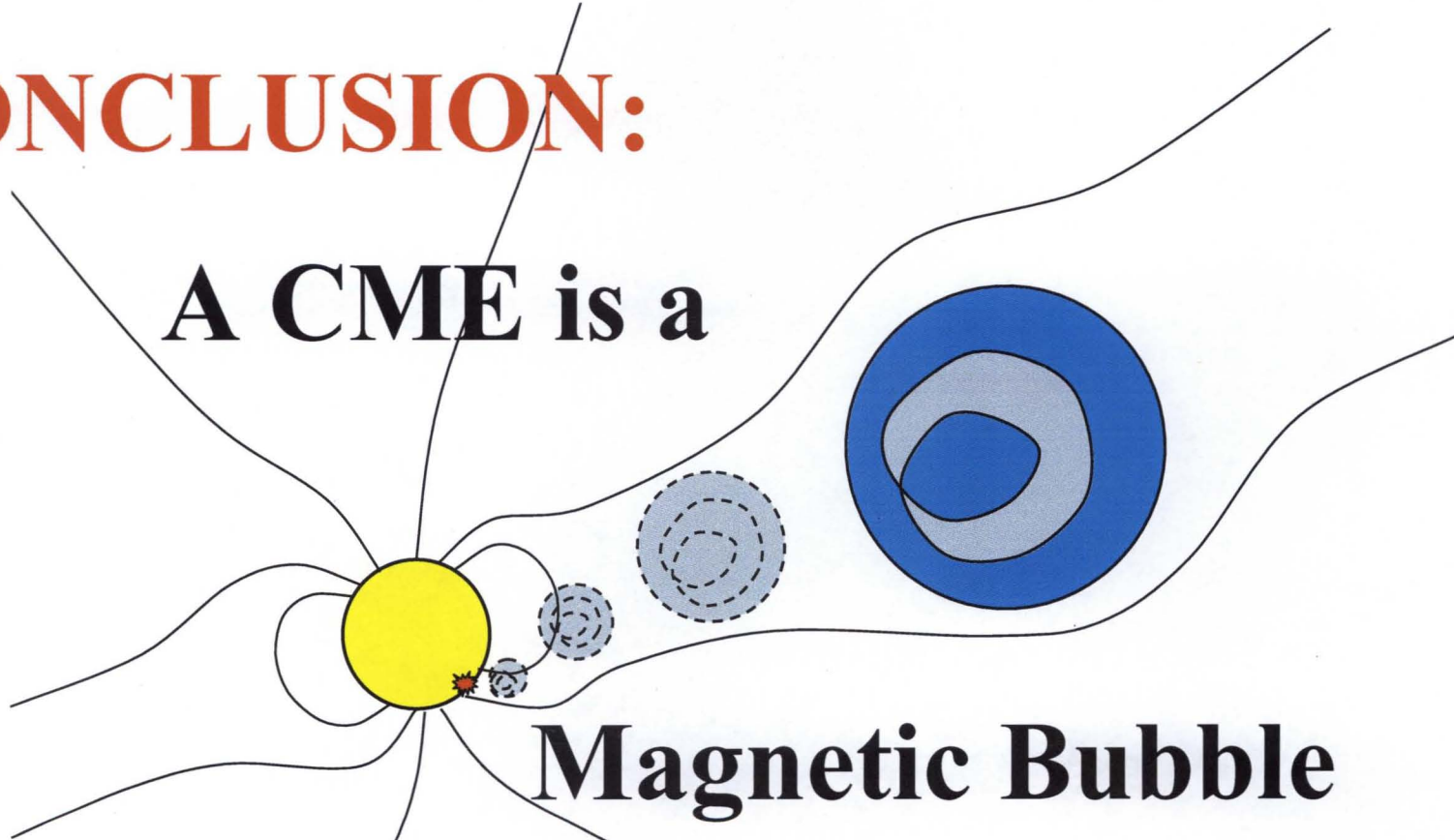
CME (date)	Source Region	θ_{CME} (deg)	θ_{Flare} (deg)	Required* B_{Flare} (Gauss)	Required B_{Flare} Fits Source Region? (Yes/No)	Source Region** Mag. Energy (ergs)
2002 May 20	Centered on small δ spot	41	2.2	≈ 490	Yes	$\sim 10^{32}$
1999 Feb 9	Quiet region filament arcade	64	27	≈ 8	Yes	$\sim 10^{32}$
2003 Nov 4	Centered on giant δ spot	128	8.7	≈ 300	Yes	$\sim 10^{33}$

* Required $B_{\text{Flare}} \approx 1.4(\theta_{\text{CME}}/\theta_{\text{Flare}})^2$ Gauss

** Source Region Magnetic Energy $\equiv (B_{\text{Flare}}^2/8\pi)(\theta_{\text{Flare}} R_{\text{Sun}})^3$

CONCLUSION:

A CME is a



Magnetic Bubble

- **Low-beta plasmoid**
- **Built and unleashed by tether-cutting reconnection**
- **Propelled by own magnetic field pushing on surroundings**

Lateral Pressure in Outer Corona

